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Mathematical modelling for landfill leachate pollution index error estimation

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ABSTRACT

Leachate Pollution Index (LPI) is an increasing environmental scale index used to quantify and compare the landfill leachate pollution potential. LPI computation required 18 leachate parameters but it shows errors if less than 18 parameters are taken in the computation due to non-availability of certain LPI characteristics and finally leads to wrong judgement. In the present study, LPI error has been computed taking leachate characteristics data of an open dumping landfill by categorizing three sub-index such as heavy metals, inorganic and organic and missing certain LPI parameters from each sub-index. The computed LPI errors observed missing of certain heavy metals responded to unnecessary alarm such as pointing a relatively less polluted environment situation as higher polluted, while, non-availability of inorganic and organic matters lead to a false secured indicating a more polluted environment situation as less polluted. Thus, it is suggested that all the 18 parameters be included while calculating LPI.

Keywords: Leachate Characteristics, Leachate Pollution Index (LPI), LPI Error

1. INTRODUCTION

Waste disposal in open area or low lying area are being practised by communities for more than five thousand years. Many developing countries still considered open dumping as the preferred means of disposing municipal solid waste (MSW) because it is generally the easiest and the cheapest way of dealing the refuse compared to other methods like incineration and composting. The major effects that takes place in and around the dumping sites are methane emission, greenhouse effects, ozone depletion, odours, generation of leachate and water pollution etc. (Chakma and Mathur 2007; Chakma, 2008).

Leachate is the liquid effluent from the landfill, which is generated from interaction of biochemical decomposition product of waste and external percolated water in the landfill (Kjeldsen et al. 2002; Di Bella et al., 2012). It consists of organic, inorganic salt compounds, heavy metals, and ammonia-nitrogen compounds (Lo, 1996; Kjeldsen et al., 2002; Ahmedand Lan, 2012). The leachate characteristics are noted widely fluctuate among landfills depending on the manner of waste placement, nature of soil strata, moisture content, pH and age of waste(Leckie et al., 1979; Andreottola and Cannas,1992; Kulikowskaand Klimiuk,2008).

The leachate generated from open dumping and uncontrolled landfills maybe entered the underlying aquifer and surface water bodies arethe major threat to ecological water balance, soil and air(Chian and DeWalle,1976; Enzminger et al., 1987; Umar et al., 2010; Pandey et al.,2014), due tonon-availability of landfill liner, leachate collection and leachate treatment facilities (Enzminger et al.,1987; Kumar and Alappat,2005; Umar et al., 2010). It has also been found that the leachate production in the landfill continues for 30-50 years after closure of landfill (Arigala et al., 1995; Bilgili et al., 2007). Henceforward, remediation actions and post-closure monitoring should be done to safeguard after landfill closure till the leachate production reached ona stabilization phase and pose no further threat to the environment(D'Souza and Somashekar,2013).However, remedial and monitoring actions required huge financial investment forall the active and closed landfills (Kumar and Alappat,2005; Umar et al., 2010). A cost effective alternative by leachate pollution index (LPI) formulated using the Rand Corporation Delphi Technique (Kumar and Alappat,2004; Rafizul et al., 2012) to prioritize the landfill site that needs instantaneous remedial action by the available limited financial resources (Munir et al., 2014). Such LPI computation required frequently determination of eighteen LPI parameters, however it requires technical manpower and financial matter which is unaffordable by developing country as there exists many open dumping and uncontrolled landfill sites. As a result, many scholars have computed the landfill LPI by adopting the missing leachate parameters from other similar aged landfills and others computed by ignoring of the non-available leachate pollution parameters. However, in both case the computed LPI has error which leads to wrong decision. Because the landfill leachate parameters are depending on many factors in addition to age of the landfill and ignoring of non-available parameters also has error based on the significant weights factor of non-available elements. Therefore, the objective of this paper was to quantify the error which would be introduced on the computed LPI due to non-availability of certain LPI parameters and estimating the expected range of error in different sub –indices to avoid wrong judgment on the landfill remedial actions.

2. MATERIAL AND METHODS

2.1. Concept of Leachate Pollution Index

The leachate pollution potential of a landfill can be assessed by an index known as leachate pollution index (LPI) used in the study as suggested byKumar and Alappat.(2003). LPI is an increasing environmental scale index, where the higher index values confirm the poorest environmental situations (Munir et al., 2014; Manimekalai and Vijayalakshmi,2012). The LPI can be computed using Equation (1) when all 18 leachate parameters are available; otherwise Equation (2) can be used (Chakma et al. 2011).

$$\mathrm{LPI} = \sum_{i=1}^{n} w_i p_i \qquad (1)$$

Where:

LPI: The weighted additive leachate pollution index

wi : The weight for the i^{th} pollutant variable

pi : The sub index score of the i^{th} leachate pollutant variable

n: Number of leachate pollutant variables used in calculating *LPI*; and $\sum_{i=1}^{n} w_i = 1$

$$\mathrm{LPI} = \frac{\sum_{i=1}^{m} m_i p_i}{\sum_{i=1}^{m} w_i} (2)$$

Where: m is the number of available leachate pollutant parameters, however when m < 18 and$\sum_{i=1}^{m} w_i < 1$.

The LPI values computed herein as the aggregate sum of three sub-indices using Eq. (3) which was developed by Kumar and Alappat (2005a) as:

$$0.23211LPI_{org} + 0.2556LPI_{ino} + 0.5102LPI_{heavy} \ (3)$$

2.2. Errors Involved on computed LPI during Non-availability of Certain Leachate Parameters

To compute the error which isbeing involved inLPI computation during non-availability of certain leachate parameters, an open dumping leachate parameters were taken from Okhla landfill site (Kumar and Alappat, 2004). The missing leachate parameters of the landfill were acknowledged from similar aged landfill site and have been accredited as the true values. The LPI error was quantify by finding the difference values between the actual and the computed LPI. In order to compute the LPI,theopen dumping leachate parameters were divided into three sub-indicesand the overall LPI was determined by aggregating of three sub-indices using Eq.(3).

The actual LPI was quantified using eighteen leachate parameter according to Eqs. (1) and (3) and its determined value has been presented on column one in Table 1.0.,while the computed LPI were determined using Eqs.(2) and (3)as certain leachate parameters are do not available in each sub-indices and its determined values have been shown from col. (1) to (9) for heavy metals under heavy metal sub-index; col. (10) to (14) for inorganic elements under inorganic sub-index and col. (15) to (18) for organic elements under organic sub index respectively on the same Table 1.0. Ignoring of leachate parameters were performed through step by step removing one lowest significant weight factor, then two, three and so on to the highest significant weight factors in each sub-index as it shown in Table 1.0. The sequence followed for LPI computation when certain numbers of leachate parameters were being missing in each sub index, first, ignore done heavy metal parameter having lowest significant weight factors and leaving all higher significant weight factors over it in heavy metal sub –index and all parameters of inorganic and organic sub-indices. Then LPI was computed using Eqs. (2) and (3) to quantifying error which was introduced during missing of one heavy metal, as it shown in column 1 in Table 1.0 under heavy metal sub-index. Next, removed two lowest significant weigh factor elements of heavy metal and leaving other higher significant weight factors over these elements in heavy metal sub-index and all elements of inorganic and organic sub-indices, to quantify error which was involved due to missing of two heavy metal elements, as it shown in column two in Table 1.0 under heavy metal sub-index. These procedures were followed to remove three, four, and five and so on till nine elements of heavy metal based on their significant weight factor arrangement to quantify the error involved which was associated with the number of missing heavy metal elements in heavy metal sub-index as it is shown from col. (2) to (9) in Table 1.0. On the next sub-index, ignoring of elements was being performed from inorganic sub-index via leaving all elements of heavy metal and organic sub-indices to quantify error which was introduced during missing of inorganic parameters.

A single lowest significant weight factor element was removed from inorganic sub-index first and then the LPI was computed by considering higher significant weight factor elements over it under inorganic sub-index and all elements of heavy metal and organic sub-index to quantify error which was introduced due to missing of a single inorganic elements as it shown in column ten in Table 1.0 under inorganic sub-index. Then again two lowest significant weight factors elements of inorganic were removed and LPI was being computed via using higher weight factor elements of inorganic and all elements of organic and heavy metals to quantify error which was introduced due to missing of two lowest significant weight factor elements of inorganic as it shown in column eleven in Table 1.0. This procedure would be followed till all parameter of inorganic removed according with their respective significant weight factors to quantify the magnitude of error involved associated with the number of missing inorganic parameters as it shown from col. (2) to (14) in Table 1.0.Finally a similar procedure would be followed for organic sub –index by ignoring elements from organic sub-index starting from a single element of the lowest to the highest significant weight factors and LPI was computed by considering higher significant weight factor elements of organic sub-index and all elements of heavy metal and inorganic sub-indices to determine the magnitude of error which was involved associated with the number of missing organic parameter as shown from col(15) to (18) in Table 1.0. At the end, the percentage error was determined due to missing of certain LPI parameters in each sub-index by dividing the net difference between the actual and the computed LPI divided by the actual LPI value. Table 1.0 show the values of the actual LPI and the LPI errors which were involved due to missing of certain leachate parameters from col. (1) to (18).

3. RESULT AND DISCUSSION

3.1. Error Involved on computed LPI due to Non-availability of Leachate Parameters

Error has been occurred on computed LPI due to non-availability of certain numbers of heavy elements in heavy metal sub-index as shown in Table 1 and Figure 1. It can be depicted that 2.63 % error was introduced on computed LPI when ignored only one lowest significant weight factor heavy metal and 3.59% and 13.597% errors when removed three and four heavy metal elements. Then the computed LPI error magnitude gradually increased corresponding with the number of missing elements increased to five, six and so on to eight. The maximum error 100% was detected in heavy metal sub-index when ignored eight heavy metal elements but the computed LPI error dramatically returned below zero when ignored all heavy metals. Therefore, in the case of limited resources to determine all heavy metal parameters, ignoring of the lowest four significant weight factor elements in heavy metal sub-index is possible because only 13.59% of error could be introduced. However ignoring more than four heavy metal elements make the error exaggerate and leads to wrong decision by giving more polluted alarm for less polluted environment which does not need remedial action. A similar producer were followed for inorganic sub–index region, ignoring of two lowest significant weight factor elements of inorganic found to have low impact on the computed LPI contributed only -10.94% error. However, if the number of missing elements increased to three, four and so on to five, the LPI errors were dramatically increased negative 80% as shown in Table 1 and Figure 2. To be more economical in the case of limited resources it is better to be ignored chloride and TDS determination if the other LPI parameters are available. But, four or five leachate parameters to be ignored from inorganic sub-index lead to more errors by giving less polluted alarm for more polluted environment which needs immediate remedial action.

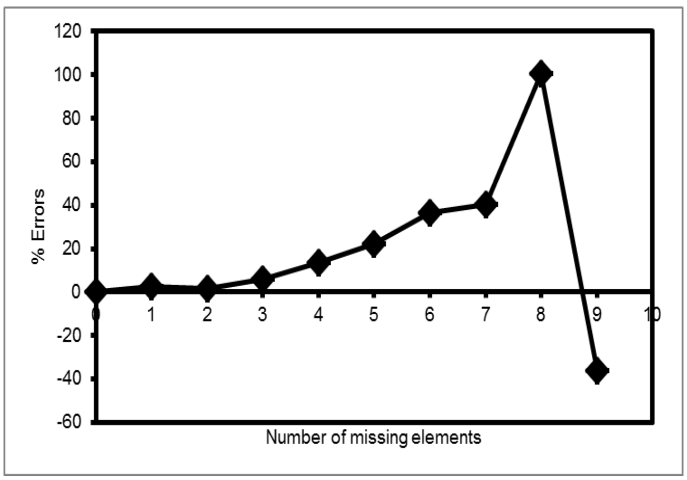

Figure 1 LPI Error in heavy metal Sub-Index

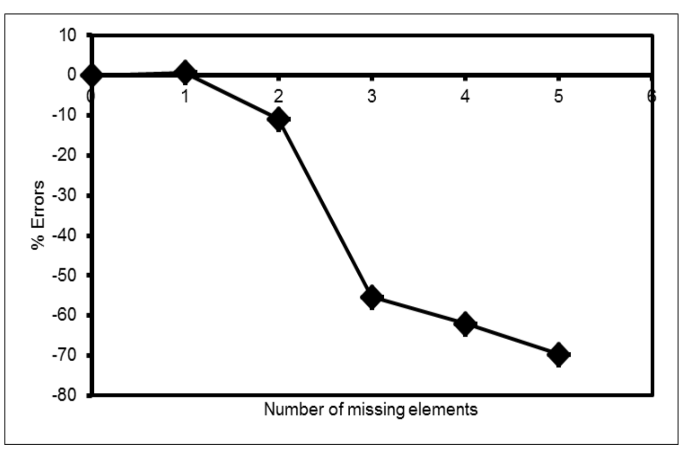

Figure 2 LPI Error in Inorganic Sub-Index

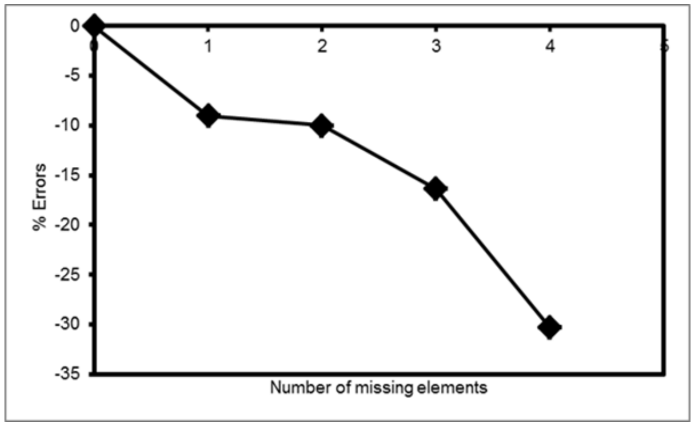

Figure 3 LPI Error in organic Sub-Index

The percentage LPI error which was introduced when certain organic leachate parameters were ignored for organic sub-index were shown in Table 1 and Figure 3. Ignoring of the lowest two significant weight factor elements of organic has low impact which contributed -10 % error but ignoring of three and four organic elements dramatically increased errors up to -35 %. The behaviour of organic sub-index error was similar to inorganic sub-index which provides less alarm for more polluted environment. However organic sub-index has the low error magnitude comparison to inorganic and organic sub-index.

Table 1 The Leachate Pollution Index and Estimated LPI Error during Missing of Certain Leachate Paramters

Index	Parameters	Weight (Wi)	Pollutant	Sub-Index (Pi)	Wi.Pi	Number of missing Heavy Metals									Number of missing inorganic Element					umber of Missing Organic Eleme			
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LPI Org	COD	0.267	23306	83	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	22.16	0.00
	BOD	0.263	1848	38.4	10.1	10.1	10.1	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	0.00	0.00
	Phenolic	0.246	1.9	6.25	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	0.00	0.00	0.00
	Coliform	0.224	500	64	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	14.34	0.00	0.00	0.00	0.00
	Sub Weight	1			48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	48.13	33.80	32.26	22.16	0
LPI-Ing	pH	0.214	8.4	5	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	0.00	1.07	1.07	1.07	1.07
	TKN	0.206	450	12.28	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	2.53	0.00	0.00	2.53	2.53	2.53	2.53
	NH4-N	0.198	745	83	16.43	16.43	16.43	16.43	16.43	16.43	16.43	16.43	16.43	16.43	16.43	16.43	0.00	0.00	0.00	16.43	16.43	16.43	16.43
	TDS	0.195	21040	48	9.36	9.36	9.36	9.36	9.36	9.36	9.36	9.36	9.36	9.36	9.36	0.00	0.00	0.00	0.00	9.36	9.36	9.36	9.36
	Chlorides	0.187	16000	100	18.7	18.7	18.7	18.70	18.70	18.70	18.70	18.70	18.70	18.70	0.00	0.00	0.00	0.00	0.00	18.70	18.70	18.70	18.70
	Sub Weight	1			48.09	48.01	48.09	48.09	48.09	48.09	48.09	48.09	48.09	48.09	29.39	20.03	3.60	1.07	0.00	48.09	48.09	48.09	48.09
LPI-Heav	Chromium	0.125	16.9	99	12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38	0.00	12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38	12.38
	Lead	0.123	0.72	11	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	0.00	0.00	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35
	Mercury	0.121	0.4	47	5.69	5.69	5.69	5.69	5.69	5.69	5.69	0.00	0.00	0.00	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69
	Arsenic	0.119	1.5	9.8	1.17	1.17	1.17	1.17	1.17	1.17	0.00	0.00	0.00	0.00	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
	Cyanide	0.114	1.1	10	1.14	1.14	1.14	1.14	1.14	0.00	0.00	0.00	0.00	0.00	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	Zinc	0.11	3.38	0.18	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Nickel	0.102	0.1	5	0.51	0.51	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
	Copper	0.098	4.25	35	3.43	3.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
	Iron	0.088	108	6.6	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
	Sub Weight	1			26.26	25.68	22.25	21.74	21.72	20.58	19.42	13.73	12.38	0.00	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26
	Derived LPI				36.86	37.83	37.41	39.04	41.87	44.98	50.31	51.71	73.97	23.46	37.13	32.83	16.46	14.00	11.17	33.54	33.18	30.84	25.69
	Error				0.00	2.63	1.49	5.91	13.59	22.02	36.47	40.27	100.7	-36.3	0.73	-10.94	-55.34	-62.03	-69.69	-0.09	-0.10	-0.16	-0.30

All values in mg/L except pH and total coliform unit (cfu/100ml).

The source of leachate characteristics taken from (Kumar and Alappat, 2004)

4. CONCLUSION AND RECOMMENDATION

The sub-indices scenarios have been revealed that the error which was introduced on the computed LPI during missing of certain numbers of parameter have been erratic behaviours. The magnitude of error in each sub index increased associated with the number of non-available parameters; the minimum and maximum errors on the computed LPI were occurred in organic and heavy

metals sub-index region respectively. Moreover unnecessary alarm has been arisen on computed LPI when heavy metals were ignored, while false good LPI recorded when inorganic and organic leachate parameters were ignored. The quantified error in each sub-index has been promising method for selectively determine the LPI parameters in the case of limited resource. It is recommendation, a mathematical modelling determine the missing parameters should be carried out for estimating all the missing parameters for minimising the errors in computing LPI which may be developed using the multi interaction of landfill age, precipitation and temperature.

REFERENCE

1. Ahmed, F. N., & Lan, C. Q. (2012). Treatment of landfill leachate using membrane bioreactors: A review. Journal of Desalination, 287, 41-54.
2. Andreottola, G. I., & Cannas, P. I. (1992). Chemical and Biological Characteristics of Landfill Leachate. In T. Christensen, R. Cossu, & R. Stegmann, Landfilling of Waste : Leachate (Vol. 1, pp. 65-88).
3. Arigala, S. G., Tsotsis, T. T., Webster, I. A., Yortsos, Y. C., & Kattapuram, J. J. (1995). Gas generation, transport, and extraction in landfills. Journal of environmental engineering, 121(1), 33-34.
4. Bilgili, M. S., Demir, A., & Özkaya, B. (2007). Influence of leachate recirculation on aerobic and anaerobic decomposition of solid waste. Journal of Hazardous Materials, 143(1), 177-183.
5. Chakma, S. and Mathur, S. (2007) Leachate: A threat to Groundwater Contamination in Delhi. Water Resource Management: Challenges and Opportunities in the 21st Century" to be held at Assam University, Silchar, India, during April 23-25, 47-48.
6. Chakma, S. (2008). "Ground water and Air Pollution from Open Dumps MSW in India" 23rd Indian Engineering Congress, Warangal, Andhra Pradesh, 12-13 December, 65-67.
7. Chakma S., Jha N., Gupta V, and Bisht P. S. (2011). "Leachate and its characteristics from Open MSW Dumps." 2nd International Conference on Solid waste Management and Exhibition, 8-10 November, 2011. Kolkata, India.
8. Chian, E., & DeWalle, F. (1976). Sanitary Landfill Leachates and Their Leachate Treatment. Journal of the Environmental Engineering Division, 2(2), 411-431.
9. Di Bella, G., Di Trapani, D., Mannina, G., & Viviani, G. (2012). Modeling of perched leachate zone formation in municipal solid waste landfills. Waste management, 32(3), 456-462.
10. D'Souza, P., & Somashekar, R. K. (2013). Assessment of stabilization, temporal variation and leachate contamination potential of municipal solid waste dumpsites in Bangalore. International Journal of Environmental Protection, 3(1), 28-35.
11. Enzminger, J. D., Robertson, D., Ahlert, R. C., & Kosson, D. S. (1987). Treatment of landfill leachates. Journal of Hazardous Materials, 14(1), 83-101.
12. Kjeldsen, P., Barlaz, M. A., Rooker, A. P., Baun, A., Ledin, A., & Christensen, T. H. (2002). Present and long-term composition of MSW landfill leachate: A review. Critical Reviews in Environmental Science and Technology, 32(4), 297-336.
13. Kulikowska, D., & Klimiuk, E. (2008). The effect of landfill age on municipal leachate composition. Bioresource Technology, 99(13), 5981-5985.
14. Kumar, D., & Alappat, B. (2005a). Analysis of leachate pollution index and formulation of sub-leachate pollution indices. Journal of Waste Management & Research, 22, 230-239.
15. Kumar, D., & Alappat, B. J. (2003). A technique to quantify landfill leachate pollution. Ninth International Landfill Symposium, (pp. 243-244).
16. Kumar, D., & Alappat, B. J. (2004). Selection of the appropriate aggregation function for calculating leachate pollution index. Journal of Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management, 8(4), 253-264.
17. Kumar, D., & Alappat, B. J. (2005). Evaluating leachate contamination potential of landfill sites using leachate pollution index. Journal of Clean Technologies and Environmental Policy, 7(3), 190-197.
18. Leckie, J. O., Halvadakis, C., & Pacey, J. G. (1979). Landfill management with moisture control. Journal of the Environmental Engineering Division, 105(2), 337-355.
19. Lo, I. M. (1996). Characteristics and treatment of leachates from domestic landfills. Environment International, 22(4), 433-422.
20. Manimekalai, M. B., & Vijayalakshmi, P. (2012). Analysis of Leachate Contamination Potential of a Municipal Landfill Using Leachate Pollution Index. IOSR Journal Of Environmental Science, Toxicology And Food Technology, 2(1), 16-39.
21. Munir, S., Tabinda, A., Ilyas, A., & Mushtaq, T. (2014). Characterization of Leachate and Leachate Pollution Index from Dumping. Journal of Applied Environmental and Biological Sciences, 4(4), 165-170.
22. Pandey, J., Kaushik, P., & Tripathi, S. (2014). Assessment of Leachate Pollution Index and Greenhouse Gas Emission at MSW Dumpsites along Ganga River at Varanasi, India. British Journal of Environment & Climate Change, 4(3), 292-311.

23. Rafizul, I. M., Minhaz, M. M., & Alamgir, M. (2012). Analysis of Errors Involved in the Estimation of Leachate Pollution Index Due to Nonavailability of Leachate Parameter. Iranica Journal of Energy & Environment, 3(3), 270-279.
24. Umar, M., Aziz, H. A., & Yusoff, M. S. (2010). Variability of parameters involved in leachate pollution index and determination of LPI from four landfills in Malaysia. International Journal of Chemical Engineering, 1-6.